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Quantitative restoration targets for fish and wildlife habitats and populations in the Lower Green Bay and Fox River AOC

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ABSTRACT

The Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) is one of the most ecologically diverse but demonstrably impaired AOCs in the Laurentian Great Lakes. We outline a transparent, quantitative process for setting targets to remove two fish and wildlife-related beneficial use impairments (BUIs). The method identifies important habitats and species/species groups and weights them according to ecological and socioeconomic criteria. These weights are paired with standardized estimates of current condition ranging from 0 (worst possible) to 10 (best possible). A weighted average of the condition scores gives an overall AOC condition for each BUI, creating a baseline for setting future restoration or BUI removal targets. Weighted averages for the LGB&FR AOC yielded a current condition of 3.60 for fish and wildlife habitats and 4.65 for species/species groups. Based on achievable restoration scenarios and discussions with local experts and stakeholders, we propose removal targets of 6.0 for the "loss of fish and wildlife habitat" BUI and 6.5 for the "degradation of fish and wildlife populations" BUI. This quantitative approach illuminates multiple pathways for reaching restoration targets and facilitates informed discussions about cost effective restoration projects. According to our results, species and species groups in this AOC are generally in better current condition than habitats when compared on the same 0–10 scale. This suggests that many (though not all) desirable fish and wildlife populations in the LGB&FR AOC are able to survive in relatively degraded habitats or are able to use these habitats productively during part of their life cycle.

Introduction

The Great Lakes Water Quality Agreement (GLWQA) in North America represents one of the world's most ambitious and arguably most effective international cooperative agreements involving freshwater resources. The treaty, signed in 1972 and revised in 1978 between the United States and Canada, aims to restore the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem (International Joint Commission, 1978). Subsequent guidance by the International Joint Commission (IJC) has provided increasingly specific recommendations (e.g., International Joint Commission, 1991) for achieving the original goals of the agreement, including constructive collaborations among state, provincial, and local agencies (Botts and Muldoon, 2005).

In 1987, the IJC adopted a protocol for designating Great Lakes Areas of Concern (AOCs), where local water resources and ecosystem integrity have become severely degraded due to pollutants, habitat destruction, and other factors (International Joint Commission, 1987). Subsequently, U.S. and Canadian governments identified 43 AOCs, re-defined in 2012 as geographic areas designated by the parties where significant impairment of beneficial uses has occurred because of human activities at the local level (International Joint Commission, 2012). Each AOC is characterized by one or more beneficial use impairments (BUIs), such as degradation of fish and wildlife populations, eutrophication or undesirable algae, degradation of aesthetics, fish tumors or other deformities, and approximately ten other types of environmental impairment (Krantzberg et al., 2006). The 2012 amended protocol addressed important issues, such as climate change and aquatic invasive species, and noted the need to better address governance issues including engagement of First Nations governments (Grover and Krantzberg, 2015).

For each AOC, an assigned government agency leads the development of a Remedial Action Plan (RAP). Three stages are prescribed for RAP development and implementation. First, the nature and severity of environmental degradation in the AOC are identified. Next, goals and recommendations for reversing the degradation are formulated, and then the recommendations are implemented. The third stage includes an assessment framework that validates the accomplishment of RAP goals (International Joint Commission, 2012).

Although seven of the 43 AOCs have been officially delisted as of 2017, vague measures of accountability and little or no true enforcement of remediation mechanisms raised questions about the long-term effectiveness of the GLWQA and its implementation on a local scale (Hauserman, 2015; Tschorke, 2008). Recent delisting analyses

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have been supported by much improved assessment criteria (Angradi et al., 2017; Bellinger et al., 2016; Grapentine, 2009; Macecek and Grabas, 2011; Michigan Department of Environmental Quality, 2015), but the problem of setting objective, quantitative ecological restoration targets is ongoing and is not unique to the Laurentian Great Lakes. Bernhardt et al. (2007), for example, reported that efforts to restore rivers and streams in the U.S. are usually followed by no measurable criteria for success. When metrics are employed, they often are limited to general appearance and positive public opinion, although standards of assessment appear to be improving, especially in the U.S. and Australia (Wortley et al., 2013). Government policy generally provides little objective guidance for ecological restoration, despite the fact that government agencies annually invest millions of dollars in ecological restoration and rehabilitation efforts (Bernhardt et al., 2005; Palmer and Ruhl, 2015).

Here, we propose a transparent, quantitative method for assessing ecological restoration progress in a large, biologically diverse and degraded ecosystem, the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) in northeastern Wisconsin, USA. Specifically, we outline a process for setting targets and assessing progress for removing two regional beneficial use impairments (BUIs). Our more general goal is to provide a recipe for evaluating restoration efforts in this and other large, complex ecological systems. The recommended approach provides measurable targets for supporting the objectives of the GLWQA, U.S. Clean Water Act, and other broad environmental policy initiatives.

Study area

Green Bay is an elongated embayment of Lake Michigan separated from the main lake basin by Upper Michigan's Garden Peninsula and Wisconsin's Door Peninsula, landforms that straddle the western arc of the Niagara Escarpment (Luczaj, 2013; Syverson and Colgan, 2004). Waters from the Fox River and several other large river systems flow into Green Bay's relatively shallow glacial-derived basin, forming one of the largest freshwater estuaries in the world. >70% of the annual nutrient and sediment inputs are contributed by the Fox River watershed, which flows into the bay near the city center of Green Bay, Wisconsin (Dolan and Chapra, 2012; Klump et al., 2009). The natural hydrologic connection between Green Bay and Lake Michigan (excluding the Sturgeon Bay shipping canal) occurs at the deeper, northern portion of the bay beginning at the tip of the Door Peninsula. Nutrient-rich effluent from the Fox River creates a pronounced gradient ranging from the shallow, hypereutrophic lower bay to a more oligotrophic middle and northern bay, grading into the deeper waters of Lake Michigan itself.

Following the IJC guidelines (eventually published in 1991), a formal RAP was developed and approved in 1988 for the LGB&FR AOC, the first such plan for a Great Lakes AOC (Wisconsin Department of Natural Resources, 2016). Subsequent updates were produced in 1993, 2009, and annually between 2011 and 2016. The 2009 update was particularly significant because it began the process of identifying BUIs and specific BUI removal targets. In the 2011 update, 13 BUIs were identified and described. Specific removal targets and current status of remedial actions for each BUI were included in this and subsequent updates.

The official boundary of the LGB&FR AOC, approved by the Wisconsin Department of Natural Resources (WDNR) in 2004, encompasses the lower 11.5 km (7.1 mi) of the Fox River below the De Pere dam and an 88 km^2 (34 mi^2) area of southern Green Bay to a line extending from the tip of Point au Sable to the tip of Longtail Point (Fig. 1). The contributing watershed includes the upper Fox River, Wolf River, and lower Fox River Basins (including Lake Winnebago), in addition to local tributaries not connected to the Fox River drainage (Duck Creek, Barkhausen Creek, Mahon Creek, and Wequiock Creek). To incorporate critical nearshore habitats for fish and wildlife populations using the LGB&FR AOC ecosystem, we extended this analysis to include the area 1 km inland from the LGB&FR AOC shoreline, defined here as the 177.2 m elevation contour (above mean sea level; equivalent to 177.06 m or 580.92 ft. IGLD 85). Water levels of 177.2 m or higher have occurred during only 3% of all months recorded since 1905 at the National Oceanic and Atmospheric Administration (NOAA) Monitoring Station 9,087,072 in Sturgeon Bay, making this an approximate high-water mark encompassing coastal wetlands and aquatic features of the LGB&FR AOC proper. The 1 km nearshore buffer includes tributaries used by fish and other aquatic organisms for breeding; nearshore wetlands used by birds, insects, amphibians, and other taxa that breed in or along the bay; and other habitats (hardwood swamp, shrub carr, Great Lakes beach, etc.) that directly or indirectly influence ecological dynamics in the Green Bay aquatic ecosystem. The LGB&FR AOC ecosystem obviously is influenced by a watershed that extends far beyond the 1 km buffer, but the proportion of upland habitats unrelated to the bay and Fox River increases progressively with distance from the shoreline. Hence, we limited our analysis to this relatively narrow (1 km) buffer where plant propagules, animal populations, and human influences frequently interact with the ecosystem within the officially designated AOC.

Methods

We focus on two BUIs in the LGB&FR AOC: a) degradation of fish and wildlife populations and b) loss of fish and wildlife habitat. This AOC, like many regional conservation management units, consists of many habitats, which in turn support many fish and wildlife species. Defining restoration success in such a complex mosaic is challenging and is further complicated by the temporally dynamic nature of this ecosystem (De Stasio Jr. and Richman, 1998; O'Donnell et al., 2013). Our method of assessing ecological condition and setting explicit conservation goals involves six general steps, creating a roadmap with multiple pathways for successful remediation of the two fish and wildlife BUIs:

1. Identify ecologically significant elements of the respective BUIs, in this case habitats and important species or species groups. These elements should be associated in some way with stressors that were responsible for the BUI designation.
2. Quantify the relative importance of these habitats and species/species groups based on objective ecological and socioeconomic criteria. Results provide quantitative weightings for each habitat and species/species group.
3. Formulate and apply a numerical metric for measuring condition of each habitat and species/species group. Convert raw measurements to a standardized condition score ranging from 0 (worst case) to 10 (best case).
4. Pair the weightings with the corresponding standardized condition scores for all habitats and species/species groups. Calculate a weighted average of these combinations to produce a comprehensive condition metric, again ranging from 0 (worst case) to 10 (best case) for each of the two BUIs.
5. Set a meaningful and achievable conservation target for each weighted BUI condition metric. This target becomes the condition (on the 0–10 scale) that justifies removal of the AOC BUI.
6. Identify potential management actions and restoration projects that will produce cost-effective progress toward the quantitative conservation targets for fish and wildlife habitats and fish and wildlife populations.

A subtly important step in formulating this strategy is transforming the condition scores to a standard 0–10 scale. In all cases, we define a score of 10 as the best possible biotic or ecological condition given constraints that were present at the beginning of the assessment period (e.g., when the AOC was first designated). In other words, a 10 is not a pristine historical condition that is no longer attainable because of permanent deforestation, agricultural impacts on soils, urban development, global extinctions, or other irreversible environmental changes. Instead,

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